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ABSTRACT

The accident at the Three Mile Island nuclear power plant resulted from a communication failure. Following an incident at an Ohio plant a year and a half earlier, B. M. Dunn, manager of Emergency Core Cooling Systems Analysis at Babcock and Wilcox (engineers), wrote a memorandum making specific recommendations on written instructions for nuclear plant operating procedures. F. Walters, a member of the Plant Performance Services staff, still had concerns about the recommendations and did not forward them to the utilities concerned. While Walters investigated these concerns, the accident at Three Mile Island occurred. Shortly thereafter, the Operating Plant Services division of Babcock and Wilcox issued "supplementary operating instructions" to the utilities, which were almost identical to Dunn's recommendations. Although both the content of the memo and Dunn's managerial rank should have ensured compliance with the memo, the primary communication context set up by Dunn was inconsistent with the actual decision making process for his recommendations. The memo was sent to the wrong audience and was written in such a way as to preclude action. To a significant extent, the lack of effective response to his memorandum can be traced to his misinterpretation of the audiences for the memorandum. The resulting accident suggests that, no matter how good the engineering, it is not finished until organizations make decisions and take action. This requires effective communication. (HTH)

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GOOD ENGINEERING + POOR COMMUNICATION = THREE MILE ISLAND*

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abstract. The accident at Three Mile Island resulted from a communication failure. A year and a half before Three Mile Island engineers in Babcock & Wilcox recommended changes in operator procedures that, if they had been issued and followed at utilities such as at TMI, would have prevented the accident. These recommended changes were not issued primarily because of poor technical communication by the engineers and managers. The most important memorandum was sent to the wrong audiences and was written in such a way as not to get them to act on the recommendations. Engineering is not completed until organizations make decisions and take action. That requires effective communication.

The accident at Three Mile Island resulted from the failure of a communication process that was initiated on October 23, 1977 but not completed until April 17, 1979, three weeks after the accident. This was a communication failure because an event at the Toledo Davis-Besse nuclear plant on October 23, 1977 led a Babcock & Wilcox engineer and manager to request changes in the operating instructions issued to utilities with Babcock & Wilcox nuclear steam supply systems. These changes, however, were never issued by Babcock & Wilcox. Had these requested changes been issued and observed by the operators at Three Mile Island, the accident would not have happened. The changes in instructions were not issued because the communication process was extremely inefficient, although considerable "communication" occurred.

Studies of the accident at Three Mile Island identify numerous "causes" of the accident, but all agree that had this communication process within Babcock & Wilcox been successful the accident would not have occurred. [1] This communication process therefore bears close examination because it illustrates how engineering problem solving is not completed until effective

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communication occurs. The changes in operating instructions requested by the engineer and manager proved to be appropriate because they essentially were those actually issued after the accident. [2] Thus, their "engineering" was good. Their request was not acted upon, however, until after the accident. Thus, their communication was poor. The result was Three Mile Island. The lesson for engineers is that, fundamentally, their engineering is not completed until their organizations take the actions their engineering indicates. That requires effective communication.

The Communication Process

The communication process consisted of a sequence of activities that commenced with an event at Davis-Besse on October 23, 1977 and concluded with revised operator instructions being sent to the utilities on April 4 and 17, 1979. [3] An engineer in Babcock & Wilcox, Mr. J. J. Kelly, hypothesized that the event at Davis-Besse may have resulted because the operators at Davis-Besse may have had inappropriate operating instructions. He therefore wrote a memorandum in which he requested changes in those instructions. This request initiated a series of communications in Babcock & Wilcox that form this specific communication process. The communication process was completed when the issue was resolved and the revised instructions issued to the utilities. (The process would have been completed had the decision been not to issue any changes in operating instructions. Although that would have been poor engineering, the communication would have been effective in the sense that conclusive organizational action would have been taken.)

The communication process has five memoranda of considerable interest, as outlined in Figure 1, The Communication Process. It has the initial memorandum by J. J. Kelly on November 1, 1977, a memorandum by F. Walters on November 10, 1977, a first memorandum by Bert M. Dunn on February 9, 1978, a second memorandum by Bert M. Dunn on February 16, 1978, and a memorandum by D. F. Hallman on August 3, 1978. It also has two important oral communication situations. This particular communication process was interrupted by the accident at Three Mile Island on March 28, 1979. Within this communication process the first Dunn memorandum perhaps is the most important, and best illustrates the commuication failure.

On October 23, 1977 the operators at the Davis-Besse nuclear plant near Toledo prematurely shut off the high pressure injection (HPI) system, which is an emergency core cooling safety system for supplying water to the hot reactor core in case of a loss of water in the regular core cooling system.[4] The operators shut off the emergency cooling water system because they had misinterpreted some instrument readings. Bert M. Dunn says in his first memorandum that "had this event occurred in a reactor at full power [Davis-Besse was operating at 9% power]...it is quite possible, perhaps probable, that core uncovery and possible fuel damage would have resulted." The

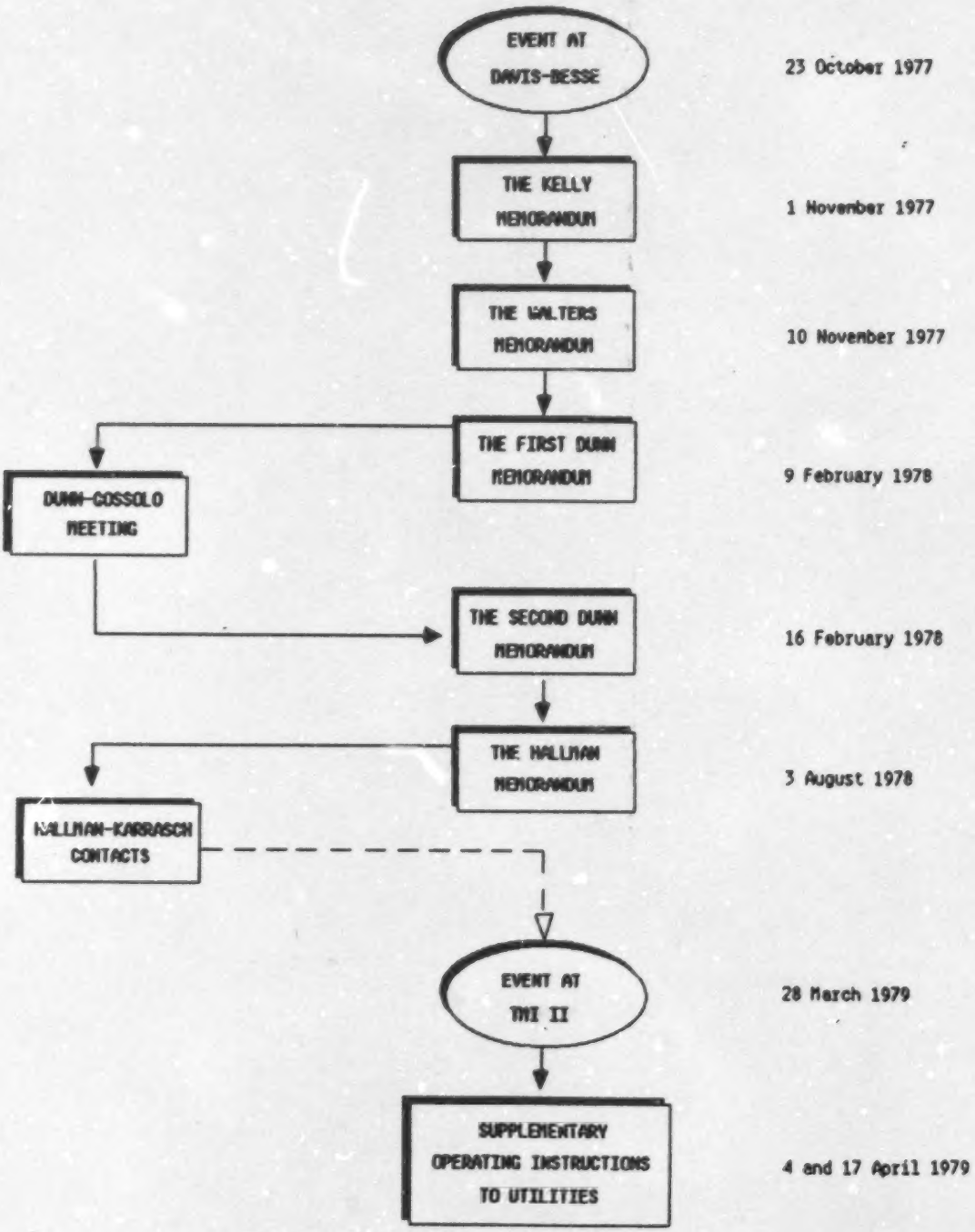

Figure 1. The Communication Process

"virtually identical"[5] event occurred at Three Mile Island. The reactor at TMI, however, was operating almost at full power, which is why Mr. Dunn testified that had his "instructions been followed at TMI" there would have been only a minor incident. [6]

Because of concerns within the Plant Design section at Babcock & Wilcox over the Davis-Besse event, on November 1, 1977 J. J. Kelly wrote a memorandum in which he recommended guidelines for nuclear plant operators on when the high pressure injection system could be safely shut down. He said that "perhaps we are not giving our customers enough guidance on the operation of the high pressure injection system." He sent the memorandum to seven managers and engineers in sections and departments within Babcock & Wilcox ranging from Safety Analysis and Emergency Core Cooling Systems Analysis to Training and Plant Performance Services. He received one memorandum in response.

In response to the Kelly memorandum, F. Walters on November 10, 1977 wrote a memorandum to Mr. Kelly. Mr. Walters, a member of the Plant Performance Services section, said that in view of operator training he thought that the operators at the Davis-Besse plant had responded correctly. He said he thought that leaving the HPI system on would result in the core cooling system becoming completely filled with water (in this state, called "solid," the operators have no means of regulating the pressure in the system) and possibly lead to some equipment failure. In subsequent testimony it became clear that Mr. Walters had misinterpreted the exact situation at Davis-Besse to which Mr. Kelly had referred. The Walters memorandum marked a stage in the communication process. Mr. Kelly had requested a decision (e.g., recommended guidelines), but operationally his request was rejected when Mr. Walters responded negatively.

Because the problem still was not resolved to his satisfaction, Mr. Kelly reactivated the communication process. Mr. Kelly asked Bert M. Dunn, Manager of Emergency Core Cooling System Analysis, to write a follow-up memorandum. On February 9, 1978, therefore, Mr. Dunn wrote a memorandum raising his "serious concern" about premature operator termination of the high pressure injection system. He made specific recommendations on written instructions for nuclear plant operating procedures and said the matter deserves "prompt attention." In response, Mr. Walters asked a member of his staff, a Mr. Gossolo, to meet with Mr. Dunn. One of his concerns was to reword the recommended operating instructions in order to clarify them for the operators.

After his meeting with a member of Mr. Walters' staff, Mr. Dunn wrote a follow-up memorandum on February 16, 1978 presenting the revised recommendations "for terminating high pressure injection following a LOCA [Loss of Coolant Accident]." At this point, both Mr. Dunn and Mr. Kelly assumed that the issue first raised by Mr. Kelly had been resolved. They assumed that the recommended guidelines in operating procedures would be forwarded to the utilities, such as Metropolitan Edison at TMI,

with reactors designed by Babcock & Wilcox. They did not know that Mr. Walters still had concerns about the system going solid and therefore did not send the recommendations to Operating Plant Services to be forwarded to the utilities. The second Dunn memorandum therefore concluded another stage of the communication process because Mr. Kelly and Mr. Dunn assumed the process had been completed.

The decision making and therefore the communication process, however, had not been completed. The communication process was resumed six months later on August 3, 1978. Mr. Walters wrote a memorandum, signed by D. F. Hallman, Manager of Plant Performance Services, to the Manager of Plant Integration, Mr. B. A. Karrasch, asking him to investigate concerns about leaving the high pressure injection system on. Mr. Walters specifically asked that two concerns about possible equipment damage be evaluated. The memorandum asked that Plant Integration "resolve the issues" of how the high pressure injection system should be operated. This memorandum drew no response.

Because the memorandum had drawn no response, Mr. Hallman followed up in person. He informally contacted Mr. Karrasch and asked for a response. He was told that could "expect an answer." [7] In February or March of 1979, shortly before the accident at Three Mile Island, not yet having received a response, Mr. Hallman met Mr. Karrasch in the hallway and got a brief oral response that, when he got back to his desk, he realized was ambiguous. He was unable to reach Mr. Karrasch by phone before the accident at Three Mile Island late in March.

Shortly after the accident at Three Mile Island, on April 4, 1979 and on April 17, 1979, Operating Plant Services of Babcock & Wilcox issued "supplementary operating instructions for the high pressure injection system" to the utilities. The instructions from a "practical standpoint" were almost identical to those formulated by Mr. Dunn on February 1978. [8] Final distribution of these instructions on April 17, 1979 concluded the specific communication process precipitated by the event at Davis- Besse on October 23, 1977.

The Importance of the Dunn Memorandum

The first Dunn memorandum, on February 9, 1978, is central to the communication process. The second Dunn memorandum, on February 16, 1978, is an addendum to the first, prepared after a short feedback loop in this stage of the communication process. The Kelly memorandum, written by an engineer, raised a serious concern. The Dunn memoranda, written by the Manager of Emergency Core Cooling Systems Analysis, should have resulted in effective action. As Mr. Dunn testified, he held "a highly responsible position." [9] Therefore, when he requested a change in the operator procedure for termination of high pressure injection he should have drawn a conclusive response.

Since Mr. Dunn was a manager, one would expect a serious

memorandum from him to get action regardless of the subject matter. Mr. Dunn identified himself as Manager of ECCS Analysis, and his memorandum has the tone of decisiveness one associates with a manager. It therefore assumes importance as communication. This was testified to by Mr. Dunn himself, who said he may have written perhaps four or five memoranda of this sort in the past few years. It was not a matter of, as Chairman Kemeny put it, "flooding the company with memoranda of this kind." [10] Thus a memorandum from Mr. Dunn in itself was an important communication act.

The Dunn memorandum, however, was also extremely important for its subject matter, as a careful reading indicates (see Figures 2 and 3, The Dunn Memorandum). It requested changes in operator procedures to prevent "probable...core uncovery and possible fuel damage." The substantive importance of the Dunn memorandum was dramatized by Commissioner Peterson, who was questioning Mr. Karrasch about his priorities [11]:

> It would appear to me that if you had the foresight that none of us had, that this failure to respond to the Dunn memo, for example, would have led to a major threat to safety of a community, to hundreds of millions of dollars of costs, to the establishment of a Presidential commission, that you probably would have given this pretty high priority, and the chairman of the board and the president and all of you would have been burning the midnight oil to respond to it.

The Dunn memorandum thus deserves close analysis.

The Failure of the Dunn Memorandum

The Dunn memorandum raises an organizational issue for Babcock & Wilcox that could not have been more serious. It concludes with the statement: "This is a very serious matter that deserves our prompt attention and correction." Why, then, did the memorandum fail? Why did Babcock & Wilcox fail to give the memorandum their prompt attention and take corrective action? An analysis of the testimony before the President's Commission and of the memorandum itself provides some clues.

The failure of the Dunn memorandum primarily seems to have been the result of ineffective analysis of his audiences by Mr. Dunn. It secondarily seems have been the result of ineffective memorandum design. Mr. Dunn sent his memorandum to the wrong persons. Then, when the appropriate persons received the memorandum they failed to pay serious attention to it. As a piece of written communication the memorandum does not seem to have been conceived and designed to get their attention.

Ineffective Audience Analysis

Given his recommendation for changes in operating instructions, Mr. Dunn's analysis of the audiences for his

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

THREE MILE ISLAND COMMISSION
EXHIBIT 3
DATE July 18-20, 1979
WITNESS

To: Jim Taylor, Manager, Licensing

From: Bert M. Dunn, Manager, ECCS Analysis (7138)

Loc.

File No. or Ref.

Subj. Operator Interruption of High Pressure Injection

Date February 9, 1978

This memo addresses a serious concern within ECCS Analysis about the potential for operator action to terminate high pressure injection following the initial stage of a LOCA. Successful ECCS operation during small breaks depends on the accumulated reactor coolant system inventory as well as the ECCS injection rate. As such, it is mandatory that full injection flow be maintained from the point of emergency safety features actuation system (ESFAS) actuation until the high pressure injection rate can fully compensate for the reactor heat load. As the injection rate depends on the reactor coolant system pressure, the time at which a compensating catch-up occurs is variable and cannot be specified as a fixed number. It is quite possible, for example, that the high pressure injection may successfully catch up with all heat sources at time t_1 and that due to system depressurization be inadequate at some later time t_2.

The direct concern here rose out of the recent incident at Toledo. During the accident the operator terminated high pressure injection due to an apparent system recovery indicated by high level within the pressurizer. This action would have been acceptable only after the primary system had been in a subcooled state. Analysis of the data from the transient conclusively indicates that the system was in a two-phase state and as such did not contain sufficient capacity to allow high pressure injection termination. This became evident at some 20 to 30 minutes following termination of injection when the pressurizer level again collapsed and injection had to be reinitiated. During the 20 to 30 minutes of noninjection flow they were continuously losing important fluid inventory even though the pressurizer indicated high level. I believe it fortunate that Toledo was at extremely low power and extremely low burnup. Had this event occurred in a reactor at full power with other than insignificant burnup it is quite possible, perhaps probable, that core uncovery and possible fuel damage would have resulted.

The incident points out that we have not supplied sufficient information to reactor operators in the area of recovery from LOCA. The following rule is based on an attempt to allow termination of high pressure injection only at a time when the reactor coolant system is in a subcooled state and the pressurizer is indicating at least a normal level for small breaks. Such conditions guarantee full system capacity and thus assure that during any follow on transient would be no worse than the initial accident. I, therefore, recommend that operating procedures be written to allow for termination of high pressure injection under the following two conditions only:

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Figure 2. The First Dunn Memorandum (2 pp.)

EXHIBIT 3
Page 2 of 2

1. Low pressure injection has been actuated and is flowing at a rate in excess of the high pressure injection capability and that situation has been stable for a period of time (10 minutes).

2. System pressure has recovered to normal operating pressure (2200 or 2250 psig) and system temperature within the hot leg is less than or equal to the normal operating condition (605°F or 630°F).

I believe this is a very serious matter and deserves our prompt attention and correction.

RMD/lc

cc: E.W. Swanson
D.E. Roy
[illegible] Karrasch
[illegible] Bailey
J. Kelly
Z.L. Kane
J.D. Agar
R.L. Pittman
J.D. Phinny
T. Scott

BEST COPY AVAILABLE

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

To Jim Taylor, Manager, Licensing November 9, 1978

From Bert M. Dunn, Manager, ECCS Analysis (2138)

Cust.

Subj. Operator Interruption of High Pressure Injection

This memo addresses a serious concern within ECCS Analysis about the potential for operator action to terminate high pressure injection following the initial stage of a LOCA. Successful ECCS operation during small breaks depends on the accumulated reactor coolant system inventory as well as the ECCS injection rate. As such, it is mandatory that full injection flow be maintained from the point of emergency safety features actuation system (ESFAS) actuation until the high pressure injection rate can fully compensate for the reactor heat load. As the injection rate depends on the reactor coolant system pressure, the time at which a compensating match-up occurs is variable and cannot be specified as a fixed number. It is quite possible, for example, that the high pressure injection may successfully match up with all heat sources at time t and that due to system pressurization be inadequate at some later time t2.

The direct concern here rose out of the recent incident at Toledo. During the accident the operator terminated high pressure injection due to an apparent system recovery indicated by high level within the pressurizer. This action would have been acceptable only after the primary system had been in a subcooled state. Analysis of the data from the transient currently indicates that the system was in a two-phase state and as such did not contain sufficient capacity to allow high pressure injection termination. This became evident at some 20 to 30 minutes following termination of injection when the pressurizer level again collapsed and injection had to be reinitiated. During the 20 to 30 minutes of noninjection flow they were continuously losing important fluid inventory even though the pressurizer indicated high level. I believe it fortunate that Toledo was at an extremely low power and extremely low burnup. Had this event occurred in a reactor at full power with other than insignificant burnup it is quite possible, perhaps probable, that core uncovery and possible fuel damage would have resulted.

The incident points out that we have not supplied sufficient information to reactor operators in the area of recovery from LOCA. The following rule is based on an attempt to allow termination of high pressure injection only at a time

Figure 3. The First Dunn Memorandum (retyped, 2 pp.)

when the reactor coolant system is in a subcooled state and the pressurizer is indicating at least a normal level for small breaks. Such conditions guarantee full system capacity and thus assure that during any follow on transient would be no worse than the initial accident. I, therefore, recommend that operating procedures be written to allow for termination of high pressure injection under the following two conditions only:

1. Low pressure injection has been actuated and is flowing at a rate in excess of the high pressure injection capability and that situation has been stable for a period of time (10 minutes).

2. System pressure has recovered to normal operating pressure (2200 or 2250 psig) and system temperature within the hot leg is less than or equal to the normal operating condition (605 F or 630 F).

I believe this is a very serious matter and deserves our prompt attention and correction.

BMD/lc

cc: E. W. Swanson
D. H. Roy
B. A. Karrasch
H. A. Bailey
J. Kelly
E. R. Kane
J. D. Agar
R. L. Pittman
J. D. Phinny
T. Scott

memorandum was surprisingly inadequate and inappropriate. The primary communication context he established was inconsistent with the actual decision making process for his recommendation--he sent it to the wrong person and omitted important audiences. In addition, he established the wrong priorities among the audiences on his distribution list. The lack of effective response to his memorandum to a significant extent can be traced to his misinterpretation of the audiences for his memorandum.

The decision making process for the issue Mr. Dunn addressed involved departments in the two separate units of the Nuclear Power Generaton Division, Nuclear Services and Engineering (see Figure 4, Audiences for the Dunn Memorandum). Mr. Dunn, however, essentially wrote within Engineering. Mr. Dunn was a manager in Engineering, the department responsible for nuclear plant design. The issue he was addressing, however, was an issue of plant operations. It involved Plant Performance Services and Operating Plant Services and even Training--all departments in Nuclear Services. The manager of Plant Performance Services would act on Mr. Dunn's recommendation, and the managers of Operating Plant Services and Training would be responsible for implementing the changes in operator procedures requested in the memorandum. The Dunn memorandum, however, addressed audiences primarily within Engineering. His primary audience was in Engineering rather than in Nuclear Services. His distribution list mostly addessed persons in Engineering.

The Dunn memorandum was addressed to Mr. Taylor, the manager of Licensing and included three additional persons in Licensing on the distribution list. Mr. Dunn testified he addressed Mr. Taylor because Mr. Taylor "was an influential person concerned with safety and could, so to speak, start the ball rolling." [12] Subsequently (presumably after the TMI accident) Mr. Taylor told him "he felt the memo was misdirected and for resolution should have gone to nuclear service" since "it was a matter of a changing (sic) procedure" [13] rather than of equipment or design, which would have involved Mr. Taylor. Mr. Taylor testified that he thought the Dunn memorandum had been misdirected "in the sense that the operating instructions that are issued to the plant do not originate in the Licensing Section." [14] Since the role of Licensing was to address issues of plant design in connection with licensing activities rather than issues of plant operation, Mr. Dunn's judgment concerning the primary audience for hi memorandum indeed was questionable.

In addition to its primary audience, the Dunn memorandum had ten persons on its distribution list. Seven of these, however, were in Engineering; only three were in Nuclear Services. Those in Engineering included three persons in Licensing and three in Plant Integration as well as the manager of Plant Design. Since Mr. Taylor, the primary audience, was in Licensing, the three persons from Licensing on the distribution list did not expand the context of the memorandum. The three persons in Plant Integration were Mr. Kelly, Mr. Swanson, who was Mr. Kelly's supervisor, and Mr. Karrasch, the manager. However, since Mr.

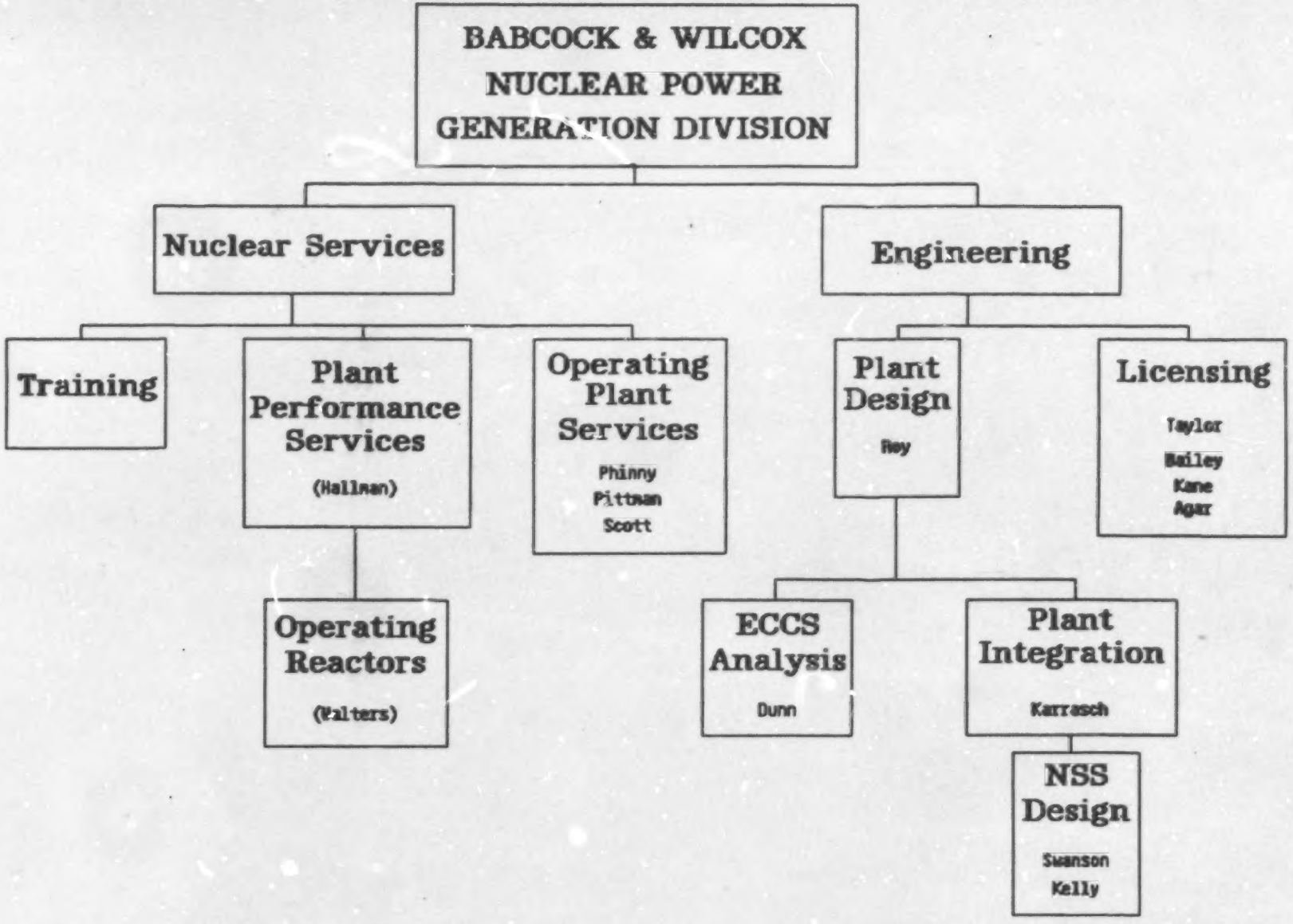

Figure 4. Audiences for the Dunn Memorandum.*

*(Hallman and Walters were not listed on the memorandum; they received it indirectly.)

Kelly had initiated the communication process with his memorandum, and had included Mr. Swanson and Mr. Karrasch as well as Mr. Dunn on his distribution list, these three persons in effect were part of the source of the Dunn memorandum, not part of its target audiences. The issue had first been raised within Integration, and again was being raised by Emergency Core Cooling System Analysis. Thus, these three persons were on the distribution list for reference purposes. The final person from Engineering on the distribution list was Mr. Roy, the manager of Plant Design, the unit in which Plant Integration and Emergency Core Cooling Systems Analysis were departments. As a higher management person for the departments requesting action, however, he would have been on the distribution list for informational purposes in this situation, not action purposes.

Thus the first seven persons on the distribution list in actuality were not in a position to act on Mr. Dunn's recommendation. These audiences therefore were inappropriate for the primary purpose of the memorandum, although some were appropriate for informational purposes.

The final three persons on the distribution list were in Nuclear Services. None, however, were perceived by Mr. Dunn as having roles of responsibility, although Mr. Phinny was the manager of Operating Plant Services. Mr. Dunn testified that each was "a member of the nuclear service department"; furthermore, from his testimony, he didn't know the title of one and didn't identify any by role or title (he identified all seven in Engineering by role or title).[15] He thus treated these audiences as very secondary, as indicated by their place at the bottom of his distribution list. He did not perceive them as having a role in the decision making on his recommendation. Presumably, he considered them to have a role in the implementation or follow up discussion of the operator instructions. Although the testimony does not address the question of how Mr. Dunn anticipated the decision he requested would be made, it is clear he did not realize that Nuclear Services was the department where the first decision would be made.

The significance of Mr. Dunn's failure to identify the appropriate decision making context for his memorandum is that the decision never was made. He did not include Dr. Hallman, the manager of Plant Performance Services who had the initial reponsibility for acting on his recommendation, as a primary audience--or even put him on his distribution list. He did not include Mr. Walters on his distribution list even though Mr. Walters had been the only person to respond to Mr. Kelly's memorandum. This should have suggested to Mr. Dunn that Mr. Walters, at least, had a role in the decision making process even if most of the persons he did put on his distribution list did not. (Mr. Walters had been delegated the responsibility by Mr. Hallman, which is why Mr. Walters responded to the Kelly memorandum and eventually wrote the Hallman memorandum.) Mr. Dunn furthermore did not include any member of Training on his

distribution list, even though his problem involved the training of operators and instructions for operators.

Thus the Dunn memorandum failed as communication. It did not establish the contexts and audiences appropriate for the recommendations it contained. Mr. Dunn consequently misdirected his second memorandum and did not know that action was never taken. He continued to think that Mr. Taylor was his primary audience for decision making purposes, while Mr. Taylor considered himself only a transmitter of communication from Mr. Dunn to Nuclear Services. Because he misunderstood the decision making process involved in his communication, Mr. Dunn never realized the significance of his meeting with Mr. Gossolo from Nuclear Services. Mr. Gossolo reported back to Mr. Walters, who blocked action on the Dunn recommendation. Not until after Three Mile Island did Mr. Dunn realize he had failed to communicate.

Ineffective Memorandum Design

Even if the appropriate management audiences had been directily addressed by the Dunn memorandum, they might not have responded to it promptly. The memorandum was not designed to get audiences to pay attention. First of all, it was not designed in terms of the organizational problem that prompted it. Second, it was unnecessarily detailed and subordinated the important information so that many readers could have failed to realize its significance.

The Dunn memorandum was written for a very specific reason: the Kelly memorandum had failed to get action. The Dunn memorandum, however, was not designed in terms of this organizational problem. Instead, it was designed in terms of the initial event at Davis-Besse--the premature termination by operators of the HPI injection system. That is, the Dunn memorandum essentially went back to the very beginning of the entire communication process. Thus it perpetuated rather than solved the organizational problem that caused it to be written in the first place.

The problem that led to the Dunn memorandum was specified by Mr. Dunn in his testimony. He said "the lack of response on the Kelly memo, or to integration in general prompted a follow-on memo by myself. I'm sure that in preparing that memo, I asked the question as to whether there had been response on this issue." He testified to a clear organizational problem. He "had not seen positive action" to the Kelly memorandum which he "could interpret as leading to instructions to prevent premature operator termination of high pressure injection." [16] The Kelly memorandum had raised concerns about operator actions; however, the Kelly memorandum had drawn little or no response within Babcock & Wilcox. This was the organizational problem that prompted this follow-up communication.

The Dunn memorandum, however, established the Babcock & Wilcox problem in terms of the premature termination of high

pressure injection at Davis-Besse. Mr. Dunn explained the operating situations with the incidents at the Davis-Besse plant in Toledo. He stated the potential operating problem in explicitly strong terms: "Had this event occurred in a reactor at full power with other than insignificant burnup it is quite possible, perhaps probable, that core uncovery and possible fuel damage would have resulted." He then asserted that the problem (from the Babcock & Wilcox perspective) was that "we have not supplied sufficient information to reactor operators in the area of recovery from LOCA" [loss of coolant accident]. This again was a strong statement (and more explicit and definite than the tentative hypothesis expressed in the Kelly memorandum).

Despite the fact that it presented a serious Babcock & Wilcox problem quite emphatically, however, the Dunn memorandum did not establish the organizational problem that provoked it. The Dunn memorandum made no reference to the Kelly memorandum. In addition, it had a significantly different distribution list than the Kelly memorandum had. The failure to reference the Kelly memorandum had the effect of denigrating it, which ironically also was Mr. Walters' attitude. The failure to establish the actual organizational problem in effect set back the communication process three months.

If the Dunn memorandum had introduced the problem that had occasioned it, perhaps important audiences might have taken notice and responded more effectively. Essentially, the memorandum was saying, "three months ago we wrote a memorandum stating that there is a possibility of core uncovery and fuel damage in our customers' reactors due to improper operator action. Yet our recommendations have not yet been acted upon." Because the memorandum ignored the immediate organizational problem and went back to a prior problem, its audiences again were able to assume that action would be taken. If they had realized that action had not been taken, they might have responded differently.

The audiences furthermore might not have responded because the memorandum is not written as though there were an urgent situation. The memorandum essentially moved from least important to most important information. It also was excessively technical, which obscured the important issues the memorandum raised. These as well as other features made the memorandum design quite inappropriate for its purpose.

As can be seen from Figures 2 and 3, the design of the memorandum subordinated the important information in such a way that a manager could well have failed to focus on that information. The memorandum moved from background to recommendation or from problem to solution, with a disproportionate amount of technical detail. This arrangement put detailed technical discussion first, and had the effect of discouraging a reader from following through to the important information at the conclusion. In particular, the important sentence about probable core uncovery came at the end of the

long, detailed second paragraph and thus lost impact.

The entire first page of the memorandum consisted of three long, excessively detailed paragraphs. While the statements about core uncovery and the recommendations were clear in themselves, their significance was buried under the technical detail and by their positioning at the ends of long paragraph blocks. The first two paragraphs of the memorandum provided a detailed technical explanation of a problem with operator interruption of high pressure injection. The first paragraph was rather theoretical, talking about time t and time t2. The second paragraph was a technical explanation of the incident at Toledo. They required close, careful reading by technically familiar readers. This in itself was not necessarily a negative feature. The technical explanation, although detailed, was clear if carefully read. It also seemed to have been technically sound, as the solution to the technical problem that Mr. Dunn proposed essentially was that actually issued after TMI. [17] Important audiences, however, misinterpreted the technical situation at Toledo either because they did not read carefully or because they misunderstood it. Because of his continuing misunderstanding, Mr. Walters had "essentially the same reaction" to the Dunn memorandum as "to the previous Kelly memo." [18]

The memorandum probably should have been totally revised. The technical explanation should have been subordinated to the actual problem and purpose of the memorandum. While necessary, it should have come in the second half of the memorandum as a technical discussion. For example, the first paragraph could have established the purpose of the memorandum in terms of the actual problem. The second paragraph could have presented the recommendation as the communication purpose, and the third paragraph could have presented the actual recommendations. These paragraphs then could have been followed by the technical discussion. This revision also could have included a division of the two long detailed technical paragraphs into shorter paragraphs to make the technical discussion easier to follow in itself.

With almost the same words, therefore, a more effective design would have been to move from most important to least important information (see Figure 5, Effective Design for the Dunn Memorandum). In addition to reversing the structure of the original memorandum, such a revision would add a purpose statement to focus reader attention on the action requested. In terms of the communication process, the technical discussion should be subordinated to the purpose and recommended decisions and actions. Readers, and especially management readers, can respond quickly and appropriately to this revision without even reading the technical discussion. Secondary audiences can read the technical discussion to evaluate the recommendation.

The memorandum had some secondary design deficiencies also. The subject line did not present the specific subject and purpose of the memorandum, which concerned a recommendation to change

THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

To Jim Taylor, Manager, Licensing February 9, 1978

From Bert M. Dunn, Manager, ECCS Analysis (2138)

Cust.

Subj. Revised Operator Instructions to Prevent Premature Termination of High Pressure Injection

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Reference: J. J. Kelly, Customer Guidance on High Pressure Injection Operation, November 1, 1977.

In his memo of November 1, 1979, Mr. J. J. Kelly pointed out the need to supply sufficient information to reactor operators in the area of recovery from LOCA. To date the guidelines he suggested have not been acted upon. However, premature operator termination of high pressure injection, as happened in a recent incident at Toledo, could lead to core uncovery and possible fuel damage in a reactor at full power.

I therefore recommend that operating procedures be written and sent to reactor operators that clearly specify when high pressure injection can be terminated. This is a very serious matter and deserves our prompt attention and correction.

Specifically, I recommend termination of high pressure injection under the following two conditions only:

1. Low pressure injection has been actuated and is flowing at a rate in excess of the high pressure injection capability and that situation has been stable for a period of time (10 minutes).

2. System pressure has recovered to normal operating pressure (2200 or 2250 psig) and system temperature within the hot leg is less than or equal to the normal operating condition (605 F or 630 F).

Technical Discussion

This memo addresses a serious concern within ECCS Analysis about the potential for operator action to terminate high pressure injection following the initial stage of a LOCA. Successful ECCS operation during small breaks depends on the accumulated reactor coolant system inventory as well as the ECCS injection rate. As such, it is mandatory tht full injection flow be maintained from the point of emergency safety features actuation system (ESFAS) actuation until the high pressure injection rate can fully compensate for the reactor heat load.

Figure 5. Effective Design for the Dunn Memorandum (2 pp.)

As the injection rate depends on the reactor coolant system pressure, the time at which a compensating match-up occurs is variable and cannot be specified as a fixed number. It is quite possible, for example, that the high pressure injection may successfully match up with all heat sources at time t and that due to system pressurization be inadequate at some later time t2.

The direct concern here rose out of the recent incident at Toledo. During the accident the operator terminated high pressure injection due to an apparent system recovery indicated by high level within the pressurizer. This action would have been acceptable only after the primary system had been in a subcooled state.

Analysis of the data from the transient currently indicates that the system was in a two-phase state and as such did not contain sufficient capacity to allow high pressure injection termination. This became evident at some 20 to 30 minutes following termination of injection when the pressurizer level again collapsed and injection had to be reinitiated. During the 20 to 30 minutes of noninjection flow they were continuously losing important fluid inventory even though the pressurizer indicated high level.

I believe it fortunate that Toledo was at an extremely low power and extremely low burnup. Had this event occurred in a reactor at full power with other than insignificant burnup it is quite possible, perhaps probable, that core uncovery and possible fuel damage would have resulted.

The incident points out that we have not supplied sufficient information to reactor operators in the area of recovery from LOCA. My recommendation for revised operator instructions to prevent premature termination of high pressure injection is based on an attempt to allow termination of high pressure injection only at a time when the reactor coolant system is in a subcooled state and the pressurizer is indicating at least a normal level for small breaks. Such conditions guarantee full system capacity and thus assure that any follow on transient would be no worse than the initial accident.

BMD/lc

Distribution: D. F. Hallman, Manager, Plant Performance Services
J. F. Walters, Supervisor, Plant Performance Services
x. x. Gossolo, Plant Performance Services
J. D. Phinny, Manager, Operating Plant Services
B. A. Karrasch, Manager, Plant Integration
E. W. Swanson, Supervisor, Plant Integration
J. J. Kelly, Plant Integration
E. R. Kane, Supervisor, Licensing

instructions to prevent operator interruption of high pressure injection. The Kelly memorandum was not referenced. And the distribution list was not ordered systematically. The primary audience also was wrong, as discussed above, so the second Dunn memorandum should have substituted D. F. Hallman for Jim Taylor, adding J. Taylor to the distribution list for informational purposes.

The design of Dunn memorandum therefore could have been a significant factor in the failure of the memorandum to achieve its purpose. An effectively designed memorandum might have overcome the deficiencies in audience analysis. It might have gotten action that would have led to changes in operator instructions that could have prevented Three Mile Island.

Effective Engineering Communication

I have been discussing a single example of communication by an engineer in considerable detail. I have done so because on the basis of my experiences with communication written by engineers in industry, this example is not at all unusual. [19] It is not unusual because the memorandum focuses on the engineering rather than on the communication. In this instance, however, although the engineering was successful, the communication was not.

Typically, engineering activities occur in an organizational context. The engineering begins in the organization and ends in the organization. The purpose of the engineering is to respond to organizational needs and to effect organizational actions. This is what "problem solving" actually is all about. [20] In a sense, the purpose of the engineering is to communicate, for without effective communication the best engineering remains in the computer, on the bench, and in the drawing. Effective communication connects the engineering to its organizational context.

Effective engineering communication therefore is designed on the basis of the relevant organizational context, not on the basis of the technical subject matter. As the TMI example suggests, that requires the engineer to design the communication in terms of the purpose of the communication, and the purpose of the communication is to solve an organizational problem. This means that the communication must be addressed to the appropriate audiences and written with them in mind.

Specifically, engineering communication should be designed in terms of the communication purpose and audience needs. This means that organizational information has priority, with technical information subordinated. The criteria for establishing priority are implicit in the actions the communication is designed to have occur in the organization. These usually are formulated in terms of conclusions and recommendations, which in turn have significance only in terms of the organizational context. The technical analysis is the

means, not the end; it is the support, not the purpose. In a sense, now that the "engineering" is done, the engineer must ask: why must I take the time to communicate? why must other engineers and managers take the time to read my communication? The answers to these questions, however, are contingent on an answer to a prior question: why did I bother to do what I did (e.g., the engineering) in the first place? In the answers to these questions are the purposes of the communication and the needs of the audiences for the communication.

My analysis and rewrite of the Dunn memorandum illustrate how the engineering communication fits into an organizational context. They explain why these questions are important to understanding the purpose of the communication. They indicate how to design the communication. Most important of all, perhaps, they dramatize a fundamental premise:

> The communication is not in the engineering
> --the engineering is in the communication.

References and Notes

1. The two major reports on the accident are Three Mile Island: A Report to the Commissioners and to the Public, Nuclear Regulatory Commission Special Inquiry Group, Mitchell Rogovin, director (Washington, D. C.: January 1980) and Report of the President's Commission on the Accident at Three Mile Island (New York: Pergamon Press, n.d., but a reprint of the Government Printing Office version issued on October 30, 1979). Both come to this conclusion, as do the others that consider this aspect of the accident.

2. Transcript of Proceedings, President's Commission on the Accident at Three Mile Island, Public Hearing, July 18, 19, and 20, 1979, pp. 95-96. The Transcipt covers the three days of hearings specifically devoted to the communication process which is the subject of this paper. My analysis is based on an analysis of this testimony and of the memoranda which are exhibits in the Transcript. The Transcript is available at the Public Document Room of the Nuclear Regulatory Commission in Washington. Copies of the revised instructions actually issued are in IE Bulletins Nos. 79-06B and 79-05B, April 14 and 21, 1979, issued by the Office of Inspection and Enforcement, U. S. Nuclear Regulatory Commission.

3. My summary of the process is drawn from the Transcript. The Rogovin Report [1] has an excellent summary of this communication process, II:1, pp. 157-161.

4. The Rogovin Report presents a "Primer on the Pressurized Water Reactor" in lay terms, I, pp. 10-15. A number of studies of TMI present similar descriptions.

5. Rogovin Report, I, p. 94. See also Staff Report on the Generic Assessment of Feedwater Transients in Pressurized Water Reactors Designed by the Babcock & Wilcox Company, NUREG-0560, Office of Nuclear Regulation, U. S. Nuclear Regulatory Commission, Washington, D. C., May 1979, p. 3-12.

6. Transcript, p. 144.

7. Transcript, p. 275.

8. Transcript, p. 96.

9. Transcript, p. 92.

10. Transcript, p. 93.

11. Transcript, pp. 256/257.

12. Transcript, pp. 61/62.

13. Transcript, pp. 68/69.

14. Transcript, p. 184.

15. Transcript, pp. 61-63.

16. Transcript, pp. 60/61, 61.

17. See note 8.

18. Transcript, p. 155.

19. Despite the seriousness of the situation, I am assuming that these actual communication practices are both routine and typical of what goes on in many organizations, especially industrial. I am not asserting that the case is representative; I leave it to engineers and managers in industry to judge for themselves how unfortunately familiar these practices are.

20. This model is explained in detail in J. C. Mathes and Dwight W. Stevenson, Designing Technical Reports (Indianapolis: Bobbs-Merrill, 1976). See especially chapters one through three for a description of the organizational communication process. Chapters four and five are relevant to my analysis of the memoranda itself.